CLAIMS

I claim:

1. A cryosurgical instrument for ablation of endocardiac tissue, comprising:

a source of a gaseous primary refrigerant, said source providing said primary refrigerant at a temperature above the critical temperature of said primary refrigerant;

a source of a liquid secondary refrigerant, said secondary refrigerant having a critical temperature higher than said critical temperature of said primary refrigerant;

a secondary expansion element connected to receive said liquid secondary refrigerant, said secondary expansion element being constructed to vaporize and expand said secondary refrigerant to a temperature below said critical temperature of said primary refrigerant;

a primary-to-secondary heat exchanger having a primary refrigerant flow path connected to receive said gaseous primary refrigerant, and a secondary refrigerant flow path connected to receive said vaporized and expanded secondary refrigerant from said secondary expansion element, said heat exchanger being constructed to cool and liquefy said primary refrigerant;

a primary expansion element connected to receive said liquid primary refrigerant from said heat exchanger, said primary expansion element being constructed to vaporize and expand said primary refrigerant to a selected cryogenic temperature; and

a cryoablation heat transfer element connected to receive said vaporized and expanded primary refrigerant.

2. A cryosurgical instrument as recited in claim 1, further comprising a flexible coaxial catheter connected at a proximal end to said primary-to-secondary heat exchanger, said coaxial catheter having an outer low pressure tube and an inner high pressure tube, said primary expansion element and said heat transfer element being located near a distal end of said flexible catheter.

3. A cryosurgical instrument as recited in claim 2, wherein:

said outer tube of said coaxial catheter is constructed of pebax polymer; and

said inner tube of said coaxial catheter is constructed of polyimide polymer.

4. A cryosurgical instrument as recited in claim 1, further comprising a compressor unit connected to receive said gaseous secondary refrigerant from said heat exchanger and to repressurize, liquefy, and return said secondary refrigerant to said secondary expansion element.

5. A cryosurgical instrument as recited in claim 1, further comprising a vent path connected to receive said gaseous secondary refrigerant from said heat exchanger.

6. A cryosurgical instrument as recited in claim 1, further comprising a compressor unit connected to collect said gaseous primary refrigerant returning from said heat transfer element.

7. A cryosurgical instrument as recited in claim 1, further comprising a vent path connected to receive said gaseous primary refrigerant returning from said heat transfer element.

8. A cryosurgical instrument as recited in claim 1, wherein said primary refrigerant has a critical temperature below about 22° C, and said secondary refrigerant has a critical temperature above about 22° C.

9. A cryosurgical instrument as recited in claim 1, wherein said primary refrigerant comprises SUVA-95, and said secondary refrigerant comprises AZ-20.

10. A cryosurgical instrument for ablation of endocardiac tissue, comprising:

a source of a gaseous primary refrigerant, said source providing said primary refrigerant at a temperature above the critical temperature of said primary refrigerant;

a compressor unit constructed to provide a liquid secondary refrigerant, said secondary refrigerant having a critical temperature higher than said critical temperature of said primary refrigerant;

a secondary expansion element connected to receive said liquid secondary refrigerant, said secondary expansion element being constructed to vaporize and expand said secondary refrigerant to a temperature below said critical temperature of said primary refrigerant;

a primary-to-secondary heat exchanger having a primary refrigerant flow path connected to receive said gaseous primary refrigerant, and a secondary refrigerant flow path connected to receive said vaporized and expanded secondary refrigerant from said secondary expansion element, said heat exchanger being constructed to cool and liquefy said primary refrigerant;

a secondary refrigerant return path connected to receive said gaseous secondary refrigerant returning from said heat exchanger and to conduct said gaseous secondary refrigerant to an inlet of said compressor unit;

a primary expansion element connected to receive said liquid primary refrigerant from said heat exchanger, said primary expansion element being constructed to vaporize and expand said primary refrigerant to a selected cryogenic temperature;

a cryoablation heat transfer element connected to receive said vaporized and expanded primary refrigerant;

a flexible coaxial catheter connected at a proximal end to said primary-to-secondary heat exchanger, said coaxial catheter having an outer low pressure tube and an inner high pressure tube, said primary expansion element and said heat transfer element being located near a distal end of said flexible catheter; and,

a vent path connected to receive said gaseous primary refrigerant returning from said heat transfer element.

11. A method for cooling a cryoprobe cold tip for ablation of endocardiac tissue, said method comprising:

providing a gaseous primary refrigerant at a temperature above the critical temperature of said primary refrigerant;

providing a liquid secondary refrigerant, said secondary refrigerant having a critical temperature higher than said critical temperature of said primary refrigerant;

providing a primary-to-secondary heat exchanger having a primary refrigerant flow path and a secondary refrigerant flow path;

flowing said gaseous primary refrigerant through said primary refrigerant flow path of said heat exchanger;

flowing said liquid secondary refrigerant through a secondary expansion element to thereby vaporize and expand said secondary refrigerant to a temperature below said critical temperature of said primary refrigerant;

flowing said vaporized and expanded secondary refrigerant from said secondary expansion element through said secondary refrigerant flow path of said heat exchanger to cool and liquefy said primary refrigerant;

flowing said liquid primary refrigerant through a primary expansion element to thereby vaporize and expand said primary refrigerant to a selected cryogenic temperature; and

exposing said cold tip to said vaporized and expanded primary refrigerant.

12. A method as recited in claim 11, further comprising:

compressing and condensing said gaseous secondary refrigerant exiting from said heat exchanger and returning said secondary refrigerant to said secondary expansion element; and

venting said gaseous primary refrigerant exiting from said cold tip.

13. A method for cryogenic ablation of endocardiac tissue, comprising:

providing a primary refrigerant at a temperature above the critical temperature of said primary refrigerant;

providing a liquid secondary refrigerant having a critical temperature higher than said critical temperature of said primary refrigerant;

providing a secondary expansion element, a primary-to-secondary heat exchanger, a flexible catheter, a heat transfer element in the distal tip of said catheter, and a primary expansion element near said heat transfer element;

inserting said flexible catheter into a blood vessel of a patient;

directing said distal tip of said catheter to a desired cardiovascular location;

vaporizing and expanding said secondary refrigerant, with said secondary expansion element, to cool said secondary refrigerant to a temperature below said critical temperature of said primary refrigerant;

cooling and liquefying said primary refrigerant with said vaporized and expanded secondary refrigerant, in said primary-to-secondary heat exchanger;

delivering said cooled and liquefied primary refrigerant to said primary expansion element near said distal tip of said catheter;

vaporizing and expanding said primary refrigerant, with said primary expansion element, to further cool said primary refrigerant; and

cooling said heat transfer element with said vaporized and expanded primary refrigerant.